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ENVIRONMENTAL INFLUENCE ON SOARING IN WINTERING RED-TAILED HAWKS

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A variety of environmental factors are known to influence the flight activity of diurnal raptors. Craighead and Craighead (1956) reported that flight by wintering Red-tailed Hawks (*Buteo jamaicensis*) decreased markedly during periods of "bad weather." Schnell (1967) demonstrated that Rough-legged Hawks (*B. lagopus*) flew significantly less as wind velocity, barometric pressure and ambient temperature decreased, and as cloudiness and relative humidity increased. Similarly, Bildstein (1978) reported that variations in solar radiation, ambient temperature, wind velocity, relative humidity and precipitation were accompanied by shifts in the flight activity of 4 species of open habitat raptors. In one of the few quantitative studies dealing exclusively with soaring flight, Henty (1977) showed that soaring activity in several raptor species increased as ambient temperatures increased.

In this study, I used multivariate statistical techniques to investigate the effects of several environmental factors on the soaring activity of wintering Red-tailed Hawks in northwestern Arkansas. I also examined the influence of environmental factors on habitat use and altitude of soaring hawks.

STUDY AREA AND METHODS

The study was conducted in a 244-km^2 area near Centerton, Benton Co., Arkansas. There the flat to gently rolling terrain comprised scattered patches of pastureland, mixed hardwoods, old fields and cultivated fields. The few distinct ridges in the study area were grown primarily in mixed hardwoods. Woodlots and pastures together comprised about 85% of the study area.

Data were collected on 12 days (6 h/day) between 14 December 1976 and 25 February 1977 and between 1 December 1977 and 28 January 1978. I located hawks by driving along secondary roads throughout the study area and did not knowingly collect data on any individual hawk more than once in a day. I measured ambient temperature and relative humidity every hour afield with a sling psychrometer. All other weather data were recorded as each hawk was observed. A Dwyer wind meter was used to measure wind velocity at chest height. Solar illumination was measured with an illuminometer. Percent cloud cover was obtained with a circular mirror, 15 cm in diameter, marked with a 25-unit grid. This technique is described in detail elsewhere (Preston 1980).

In addition to weather variables, measures of habitat use were obtained for 50 soaring hawks chosen at random. Due to time restrictions, it was not feasible to sample the habitat below every soaring hawk observed. The site above which a hawk was soaring when first observed was considered the center of a circular 0.162-ha sampling area. Four orthogonal

TABLE 1
MEAN, STANDARD DEVIATION AND RANGE OF EACH WEATHER PARAMETER

	$\bar{x}$ ± SD	Range
Ambient temp. (°C)	2.8 ± 7.31	−16.0–14.0
% relative humidity	49.5 ± 12.34	21.0–79.0
Wind velocity (mph)	10.1 ± 9.77	0.0–31.0
Solar illumination (foot candles)	702.0 ± 378.25	105.0–1800.0
% cloud cover	42.8 ± 30.96	0.0–100.0

transects were established from the center of each area, the first being set by the random position of the crosshairs of a sighting tube. Each transect was 45 m long and constituted the radius of the 0.162-ha circle. The habitat type (pasture, old field, cropland, woodlot) encountered at each of 25 random stops along each transect was recorded. These 100 stops were used to calculate habitat percentages for each sampling area. The technique is modified from James and Shugart (1970).

The soaring altitude of each of these 50 hawks was estimated using a transparent pane of glass marked with silhouette representations of Red-tailed Hawks as they would appear at various distances, up to 92 m from the observer. A taxidermy specimen was used to calibrate the scale. Only 3 of the 50 hawks were observed soaring above 92 m. Estimates derived from the scale are subject to some error due to the intraspecific size variation.

The data were analyzed using statistical programs in the computer library at the University of Arkansas. The 72 h of data were separated initially into 24 three-h observation periods (2/observation day) and the mean value of each weather variable was calculated for each observation period. The percentage of hawks soaring when first observed was also calculated for each observation period. Pearson's product-moment correlation analysis (Sokal and Rohlf 1969) was used to test for associations between environmental factors and soaring activity and habitat use. After transforming the data to minimize non-normality and heteroscedacticity (Box and Cox 1964, Sokal and Rohlf 1969, Andrews et al. 1971), a multivariate analysis of variance (MANOVA) (Morrison 1967) with a step-down procedure (Bargmann 1962) was used to test for a significant difference in soaring incidence with respect to environmental factors. Then discriminant function scores were generated and were used to characterize environmental conditions associated with soaring activity.

RESULTS AND DISCUSSION

The means and standard deviations of each weather factor are given in Table 1. Table 2 shows that the percentage of hawks observed soaring increased significantly as relative humidity and cloud cover decreased, and as wind velocity and solar illumination increased. Because these 4 variables were highly intercorrelated, partial correlation analysis (Morrison 1967) was used to clarify the association between each of these factors and the incidence of soaring. The partial correlation coefficients (wind velocity 0.907; $P < 0.001$, illumination 0.101; $P > 0.05$, cloud cover −0.103; $P > 0.05$, relative humidity −0.036; $P > 0.05$) show that only

TABLE 2

PRODUCT-MOMENT CORRELATION COEFFICIENTS FOR ENVIRONMENTAL FACTORS AND THE INCIDENCE OF SOARING DURING OBSERVATION PERIODS[a]

	Ambient temp.	Relative humidity	Wind velocity	Solar illumination	% cloud cover
% of hawks soaring	0.223	−0.729*	0.864*	0.799*	−0.765*
Ambient temperature		0.211	0.209	0.207	0.158
Relative humidity			−0.707*	−0.764*	0.758*
Wind velocity				0.701	−0.768*
Solar illumination					−0.871*

[a] Twenty-four 3-h observation periods.
* Indicates significant correlation at $P \leq 0.05$.

wind velocity was associated significantly with the incidence of soaring when other variables were held constant. Fig. 1 illustrates the observed relationship between wind velocity and incidence of soaring.

Similarly, MANOVA showed a highly significant difference in soaring activity with respect to environmental variables ($-\text{m} \ln \lambda = 76.40$, $P < 0.001$). The associated step-down procedure identified wind velocity as the only variable which, taken by itself, contributed significantly ($P < 0.001$) to the difference. The discriminant function (a linear function of the original environmental variables) stressed those factors separating soaring from non-soaring activity (Sokal and Rohlf 1969). Wind velocity, illumination, cloud cover and relative humidity were highly correlated with the discriminant function (Table 3) and thus were important in characterizing a weather gradient associated with soaring activity (Fig. 2).

In his discussion of soaring, Cone (1962) differentiated static soaring involving the use of rising air columns, from dynamic soaring involving the use of wind gradients. He further classified static soaring into declivity (or slope) and thermal soaring. Declivity currents arise when wind is de-

TABLE 3

COEFFICIENTS OF CORRELATION BETWEEN EACH WEATHER PARAMETER AND DISCRIMINANT FUNCTION (AFTER DATA STABILIZATION)

	Discriminant function
Ambient temperature	0.148
Relative humidity	−0.459
Wind velocity	0.901
Solar illumination	0.595
Cloud cover	−0.503

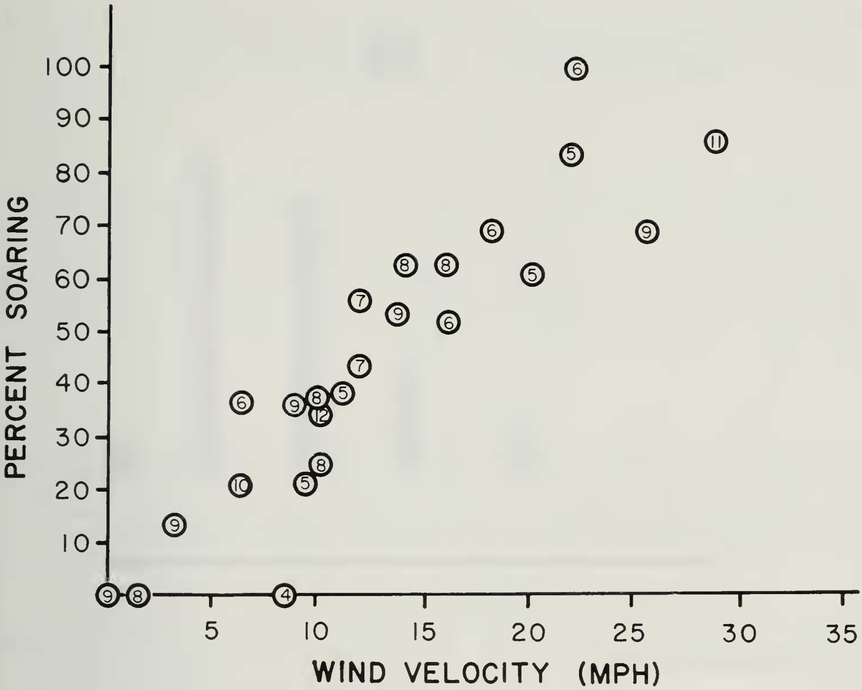

FIG. 1. Observed association between wind velocity and the incidence of soaring for each of the 24 three-h observation periods. Circled numbers indicate how many hawks were observed during each period.

flected upward by surface obstacles such as hills. Thermals are formed as surface layers of air become warmed and/or moisture-laden by the sun-heated earth. These less dense bubbles of warm air rise steadily. Cone (1962) concluded that thermal soaring was the most important method of soaring flight used by land birds. However, Pennycuick (1972) emphasized that among raptors the use of declivity currents for soaring above hillsides is very common.

The association that I found between wind velocity and soaring activity could indicate use of either declivity or dynamic soaring. Although the relatively low-aspect-ratio wings of Red-tailed Hawks are not particularly well-adapted for any method of soaring, they are common in birds specializing in static soaring (Cone 1962, Welty 1962, Pennycuick 1972). Furthermore, dynamic soaring has generally not been considered important to land soarers mainly due to the lack of a wind gradient above land masses (Pennycuick 1972). Correlation analysis showed general independence between environmental factors and habitat use. However, there was a sig-

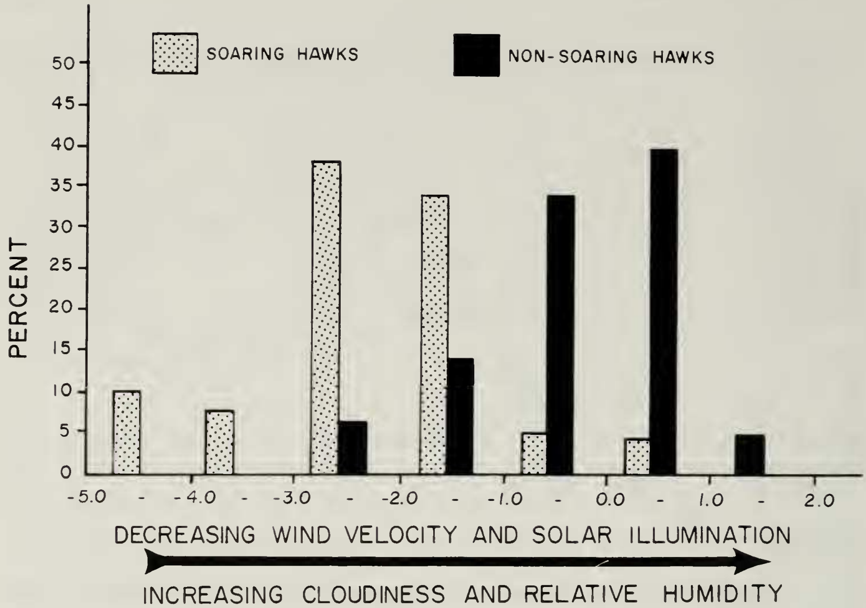

FIG. 2. Separation between soaring (N = 77) and non-soaring (N = 103) hawks along the discriminant function axis.

nificant positive correlation between wind velocity and soaring altitude ($P < 0.05$). Higher wind velocities can increase the declivity "soaring zone" surrounding hills and ridges, thus allowing the hawks to soar higher (Pennycuick 1972, Grace 1977). The relationship between wind velocity and soaring activity needs to be quantified in relatively barren, flat areas devoid of significant declivity currents. Reports by Hankin (1913), Cone (1962) and Henty (1977) indicate that increasing ambient temperature, rather than wind velocity, may be the dominant weather factor associated with soaring activity in the tropics and during temperate seasons when conditions are conducive to thermal soaring. Because adverse conditions such as fog or precipitation depress most raptor flight activity (Craighead and Craighead 1956, Schnell 1967, Bildstein 1978), it would be an oversimplification to attribute absolute control of soaring frequency to 1 environmental factor in any season or climate.

Although early reports emphasized hunting as the primary function of *Buteo* soaring, Wakeley (1978) found that Ferruginous Hawks (*B. regalis*) spent far more time soaring than predicted from capture/cost ratios for that hunting method. Thermoregulation, territorial display and exploration have been mentioned as some alternative functions of soaring (see Wakeley 1978). Studies designed to determine *Buteo* species distributions with respect to both thermal and declivity soaring opportunities will prove useful in evaluating the importance of soaring (other than migratory) as an adaptive activity.

SUMMARY

The incidence of soaring by Red-tailed Hawks wintering in northwestern Arkansas fluctuated with several weather parameters. The percentage of hawks observed soaring increased as wind velocity and solar illumination increased, and as cloud cover and relative humidity decreased. Wind velocity was the most important factor associated with soaring incidence. Hawks also soared at greater altitudes as wind velocity increased. The results are interpreted to reflect the use of declivity updrafts to soar under conditions not conducive to thermal soaring.

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